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Digital Divide and Access to Basic Services in West Africa: Empirical Evidence on Socioeconomic Determinants

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Abstract

The rapid digitalization of sub-Saharan Africa has generated considerable hope for territorial development. Yet behind the dominant discourse of technological leapfrogging lies a troubling reality: the digital divide may amplify existing inequalities rather than reduce them. This study examines this crucial question through analysis of six West African countries using Afrobarometer Round 9 data. We construct a multidimensional digital divide index integrating equipment access, internet usage, and information isolation, then quantify its association with three essential services: drinking water, health, and education.

Our results reveal three major findings that challenge current policies. First, formal education constitutes the most powerful determinant of digital inclusion, well ahead of wealth or geographic location. Second, digital divide is strongly associated with deficits in access to essential services, and this association persists even after rigorous control for territorial heterogeneity via district fixed effects models. Third, contrary to expectations, the impact of digital exclusion does not vary significantly between rural and urban areas, suggesting that marginalization transcends simple geographic dichotomy.

Keywords: digital divide, basic services, social capital, West Africa, territorial development

JEL Classification: O33, O55, H41, I38

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1 Introduction

The spectacular expansion of mobile telephony in sub-Saharan Africa has nurtured unbridled optimism regarding the reduction of territorial inequalities. New technologies were meant to enable isolated populations to directly access information, administrative services, and economic opportunities. The continent seemed poised to "leapfrog" development stages through digital technology. Yet a decade after the mobile telephony boom, reality proves more nuanced. Owning a phone hardly guarantees effective digital inclusion. Between possessing a basic device without internet connection and daily use of a connected smartphone, gaps remain abyssal.

These digital disparities raise a fundamental question for policymakers: to what extent does the digital divide amplify existing inequalities in access to essential services? The question takes on particular urgency as numerous African governments undertake progressive digitalization of their administrations. If digital exclusion reproduces and reinforces deficits in access to public goods, as several recent works suggest [11, 4, 1], then digitalization strategy could paradoxically worsen the inequalities it claims to reduce. Nevertheless, rigorous empirical evidence remains surprisingly scarce for West Africa, particularly concerning fundamental services such as water, health, and education.

This research examines two deeply interconnected questions. First, which socioeconomic and territorial factors determine digital exclusion in West Africa? Second, how is digital divide associated with access to basic services, once individual characteristics and unobserved territorial heterogeneity are controlled?

Our empirical contribution unfolds along three substantial dimensions. First, we construct a multidimensional digital divide index that decisively surpasses conventional binary measures to integrate material access, effective usage, and information isolation. This multidimensional approach, consistent with recommendations from Van Deursen & Van Dijk (2019), better captures the complexity of the phenomenon than traditional equipment possession indicators. Second, we identify determinants of digital exclusion by mobilizing an enriched theoretical framework including not only classic socioeconomic variables but also social capital and ethno-religious diversity, factors often neglected in quantitative analyses. Third, we quantify the association between digital divide and access to essential services using fixed effects models that control for unobserved territorial heterogeneity at the district level.

Our results reveal several robust stylized facts that challenge current public policies. Formal education constitutes the most powerful determinant of digital inclusion, ahead of wealth and location. This result questions approaches centered solely on infrastructure deployment. Digital divide is strongly associated with deficits in access to drinking water, health services, and educational infrastructure. These associations persist after controlling for multiple individual characteristics and territorial heterogeneity, underscoring the importance of deliberately inclusive policies accompanying progressive digitalization of public services. Against our initial expectations, the association between digital divide and services does not vary significantly according to rural or urban location, suggesting that marginalization transcends simple geographic dichotomy.

The remainder of the article is structured in four sections. Section 2 synthesizes relevant literature and formulates our research hypotheses. Section 3 presents the data, construction of our multidimensional index, and econometric estimation strategy. Section 4 exposes and interprets empirical results. Section 5 discusses theoretical and policy implications before concluding.

2 Literature Review and Hypotheses

2.1 Beyond Physical Access: A Multidimensional Approach

The conceptualization of digital divide has undergone substantial evolution over the past decade. Early work focused on the simple dichotomy between connected and unconnected, reflecting a period when the main challenge remained territorial coverage. Van Deursen & Van Dijk (2019) show that the first-level digital divide has now shifted from inequalities in physical access to inequalities in material access and effective usage. In African contexts where mobile coverage expands rapidly, technical availability no longer guarantees digital inclusion. High coverage rates can mask profound disparities in terms of equipment owned, regularity of usage, and tangible benefits derived from technologies.

Warschauer (2004) emphasizes that social appropriation of technologies requires far more than simple material access. It requires usage skills, social support facilitating learning, and perceived relevance of technologies for daily needs. This sociotechnical perspective considerably enriches our understanding: digital divide stems not solely from infrastructure deficit but from a complex set of economic, educational, social, and cultural barriers.

Büchi (2021) confirms that contemporary divide simultaneously encompasses material access, usage skills, and tangible benefits derived from technologies. This multidimensional perspective proves particularly relevant for Africa where inequalities operate simultaneously at all these levels. Ignoring one dimension or another necessarily leads to incomplete diagnoses and sub-optimal policies.

2.2 Individual and Territorial Determinants

Recent comparative analyses reveal marked disparities between and within African countries. Ndoya & Asongu (2022) show that the effect of digital divide on income inequality varies significantly according to national infrastructure development level. Countries endowed with better telecom infrastructure seem better able to leverage digital technology to reduce inequalities, while in less advanced countries, digital technology could paradoxically widen them. This heterogeneity suggests that policies cannot be uniform across the continent.

At the subnational level, Otioma et al. (2019) identify strongly clustered spatial distribution of ICT access in Kigali, correlated with infrastructure inequality and neighborhood socioeconomic status. This result illustrates that even in African capitals, digital exclusion does not distribute randomly but follows preexisting socioeconomic fault lines. Poor and peripheral neighborhoods accumulate infrastructure deficits and digital exclusion.

Sam (2019) offers an often-neglected critical perspective: the role of illiteracy and language barriers. The dominance of English and French in digital interfaces de facto excludes non-literate populations and those not fluent in colonial languages. In West Africa where literacy rates remain low in several countries and where national languages do not always have adapted digital interfaces, this cultural dimension interacts with ethnic diversity to create complex exclusion patterns that purely economic analyses fail to capture.

2.3 Digital Divide and Service Access

The relationship between digital infrastructure and access to public goods proves more complex and ambiguous than optimistic discourses about technological leapfrogging suggest. Fu et al. (2024) use Bayesian quantile regression to show that in high-inequality contexts, digital technologies tend to widen rather than narrow gaps. The effect varies across distribution quantiles: the wealthiest and best educated benefit massively from digital technology, while vulnerable populations derive little or no benefit.

Bokhari & Awuni (2023) document in North Africa that digital inequalities correlate not only with socioeconomic gaps but also with differential effects on employment and material well-being. Digital divide does not solely reflect preexisting inequalities but actively contributes to reproducing them through differential effects on labor market and household income. Those already disadvantaged find themselves further marginalized by digitalization of employment search and hiring procedures.

For West Africa, the question of interaction between digital divide and service access remains insufficiently explored. Yet this question proves crucial: progressive digitalization of administrative services, health appointments, school enrollment platforms, and even water and electricity bill payments potentially creates insurmountable barriers for populations excluded from digital technology. Without concrete data on the West African context, policies risk being poorly calibrated.

2.4 Social Capital and Ethnic Heterogeneity as Moderators

Two contextual dimensions deserve particular attention in the African context. First, social capital can potentially play a compensatory role. Sene (2012) shows that trust and local networks facilitate collective action and production of local public goods. Hollard & Sene (2016) confirm that social capital positively influences access to primary health services in sub-Saharan Africa. If this logic extends to digital domain, we might expect strong social capital to partially compensate for infrastructure deficits through mutual assistance, informal learning, and shared access.

Yet Füzér et al. (2023) introduce a critical nuance: in digital peripheral contexts, social capital can paradoxically reinforce exclusion when local networks themselves are digitally excluded. If peers in social network lack digital skills, mutual support cannot compensate for individual deficits. The question of social capital's role in digital domain therefore remains empirically open.

Second, Hollard & Sene (2020) demonstrate that ethnic diversity negatively influences quality of educational infrastructure in Africa. This finding echoes broader political economy literature suggesting that ethnic fragmentation complicates collective action and equitable distribution of public goods. If this pattern extends to digital infrastructure, we should observe more severe digital exclusion in ethnically diverse territories.

2.5 Research Hypotheses

This literature review suggests three testable hypotheses for West Africa:

H1 (Socioeconomic determinants): Formal education and wealth positively influence digital inclusion, with education exerting a particularly strong effect compared to other factors.

H2 (Association with services): Digital divide is negatively associated with access to basic services (water, health, education), even after controlling for individual characteristics and territorial heterogeneity.

H3 (Contextual moderators): Social capital partially compensates for digital exclusion in facilitating access to services, while ethno-religious diversity amplifies negative effects.

3 Data and Methodology

3.1 Data Sources

This study exploits Round 9 of Afrobarometer (2021-2023), conducted in six West African countries: Benin, Burkina Faso, Guinea, Ivory Coast, Nigeria, and Senegal. Afrobarometer provides nationally representative samples through stratified random cluster sampling.

Total sample size reaches 10,800 respondents distributed across 1,800 primary sampling units corresponding to districts or administrative subdivisions. Survey rigorously follows international standards for questionnaire administration and quality control.

Our analytical sample comprises adults aged 18 years and above interviewed face-to-face. Non-responses for key variables remain marginal (less than 2% on average), allowing reliable analyses without major selection bias. The six selected countries present varied characteristics in terms of digital infrastructure development, human capital level, institutional quality, and ethno-linguistic diversity, offering interesting variability for analysis.

3.2 Construction of the Digital Divide Index

We construct a composite digital divide index (DDI) integrating three dimensions that progressively deepen exclusion:

Dimension 1: Equipment access. First component captures whether respondent owns a mobile phone, computer, or tablet. Equipment absence constitutes first level of exclusion.

Dimension 2: Internet usage. Second component identifies whether respondent uses internet, regardless of frequency. Owning equipment without using internet represents second level of exclusion.

Dimension 3: Information isolation. Third component measures whether respondent obtains no information from radio, television, newspapers, or internet. Information isolation constitutes deepest level of exclusion.

We apply principal component analysis (PCA) to extract first component from these three variables. Resulting index explains approximately 65% of total variance, indicating these dimensions strongly covary. Index is then normalized between 0 and 1, where 0 indicates complete digital inclusion and 1 maximum exclusion. This continuous index advantageously captures gradation of digital divide compared to binary indicators.

Table 1: Component Loadings of the Digital Divide Index (PCA)

Variable	Component 1	Uniqueness
No phone/computer/tablet	0.612	0.325
No internet usage	0.634	0.298
Information isolation	0.471	0.558
Eigenvalue	1.95	
Proportion of variance	0.651	

Table 1 presents component loadings. All three variables contribute positively and substantially to first component, confirming coherence of composite index. Equipment absence and internet non-usage weigh slightly more (0.61 and 0.63) than information isolation (0.47), reflecting progressive nature of exclusion: one can be informationally isolated while occasionally using internet.

3.3 Dependent Variables: Service Access

We measure access to three essential services:

Drinking water: Binary variable coded 1 if respondent reports having piped water in dwelling or yard, and 0 otherwise (well, river, tanker, etc.).

Health infrastructure: Binary variable coded 1 if health clinic is present in village/neighborhood, 0 otherwise.

Education infrastructure: Binary variable coded 1 if primary school is present in village/neighborhood, 0 otherwise.

These indicators directly capture local availability of essential services rather than effective individual usage, thereby isolating territorial infrastructure dimension. They come from Afrobarometer questions asking respondents whether specific facilities exist in their immediate living environment.

Table 2: Descriptive Statistics of Key Variables

Variable	Mean	Std. Dev.	Min	Max
Dependent variables				
Digital divide index (DDI)	0.428	0.312	0	1
Piped water access	0.346	0.476	0	1
Health clinic presence	0.723	0.448	0	1
Primary school presence	0.891	0.312	0	1
Main explanatory variables				
Age (years)	37.4	14.8	18	99
Male (=1)	0.501	0.500	0	1
Formal education (years)	6.83	5.92	0	18
Wealth index (0-10)	4.52	2.31	0	10
Urban (=1)	0.487	0.500	0	1
Social capital index	0.531	0.214	0	1
Ethnic fractionalization	0.612	0.183	0.11	0.89
Religious fractionalization	0.441	0.168	0.03	0.74
Observations		10,800		

3.4 Explanatory Variables

Individual characteristics: We include standard sociodemographic variables: age, gender (male=1), formal education years (0 to 18), and household wealth measured by Afrobarometer asset index (0 to 10 scale aggregating ownership of consumer durables, housing quality, and access to utilities).

Urbanization: Binary variable distinguishing urban (=1) from rural (=0) residence. This geographic dimension proves crucial for capturing territorial inequalities.

Social capital: We construct social capital index following Hollard & Sene (2016) and Sene (2012). Index aggregates via PCA responses to questions on interpersonal trust, membership in community associations, and civic participation. Normalized index ranges from 0 (low social capital) to 1 (high social capital).

Ethnic and religious diversity: At district level, we calculate fractionalization indices measuring probability that two randomly selected individuals belong to different ethnic or religious groups. These indices, ranging from 0 (homogeneity) to 1 (maximum diversity), follow formula:

$$Frac_j = 1 - \sum_{i=1}^{N} s_{ij}^2 \tag{1}$$

where s_{ij} represents share of group i in district j. These indices capture ethno-religious heterogeneity potentially influencing collective action and public good provision.

3.5 Econometric Strategy

Our empirical approach unfolds in two complementary stages corresponding to two research questions.

3.5.1 Stage 1: Determinants of Digital Divide

To identify socioeconomic and territorial factors explaining digital divide, we estimate following linear model:

$$DDI_{ij} = \alpha + \beta_1 X_{ij} + \beta_2 Z_j + \gamma_c + \varepsilon_{ij} \tag{2}$$

where DDI_{ij} represents digital divide index for individual i in district j, X_{ij} is vector of individual characteristics (age, gender, education, wealth, urban location, social capital), Z_j contains district-level variables (ethnic and religious fractionalization), γ_c represents country fixed effects, and ε_{ij} is error term.

We estimate this model by OLS with standard errors clustered at district level to account for within-district correlation of errors. Country fixed effects control for all time-invariant national specificities (institutional quality, overall development level, national digital policies).

3.5.2 Stage 2: Association between Digital Divide and Service Access

To quantify association between digital divide and access to basic services, we estimate three separate models for each service:

$$Service_{ij} = \alpha + \delta \cdot DDI_{ij} + \beta X_{ij} + \theta_j + \varepsilon_{ij} \quad (3)$$

where $Service_{ij}$ is binary indicator of access to service (water, health, or education), DDI_{ij} is digital divide index, X_{ij} includes same individual controls as in equation (2), and crucially, θ_j represents district fixed effects.

District fixed effects constitute essential methodological choice. They control for all unobserved characteristics specific to each district (local infrastructure quality, history, local governance, geographic specificities). By comparing individuals within same district, we eliminate confounding from territorial heterogeneity, thus isolating net association between individual digital exclusion and service access after accounting for local context.

We estimate these models via linear probability model (LPM) rather than probit or logit for two reasons. First, LPM allows straightforward interpretation of coefficients as marginal effects. Second, with district fixed effects, LPM avoids incidental parameters problem affecting non-linear models with numerous fixed effects.

To test heterogeneity of associations, we estimate extended specifications including interaction terms between DDI and location (urban/rural) or between DDI and social capital, allowing assessment of whether digital exclusion effects vary according to context.

4 Results

4.1 Descriptive Overview

Table 2 presents descriptive statistics. Average digital divide index reaches 0.43, indicating substantial exclusion in sample. Distribution reveals considerable heterogeneity: 15% of respondents are fully included (DDI=0) while 8% face maximum exclusion (DDI=1).

Regarding services, 35% have piped water access, 72% live near health clinic, and 89% near primary school. These rates mask considerable disparities: in rural areas, piped water access falls to 18% versus 54% in urban areas. Educational infrastructure appears most widely distributed, though substantial rural-urban gap persists (84% versus 95%).

Average formal education reaches 6.8 years, concealing bimodal distribution: 23% have no schooling while 18% completed secondary or tertiary education. This educational polarization likely influences digital divide. Wealth index averages 4.5 on 0-10 scale, with standard deviation of 2.3 indicating substantial inequality.

Ethnic fractionalization averages 0.61, indicating high diversity: probability that two randomly selected individuals belong to different ethnic groups exceeds 60%. Religious fractionalization is lower (0.44) but still substantial. Social capital index averages 0.53, with considerable variation (standard deviation 0.21).

Table 3: Digital Divide by Country and Location

Country	Overall	Urban	Rural
Benin	0.389	0.312	0.476
Burkina Faso	0.512	0.421	0.583
Guinea	0.468	0.385	0.542
Ivory Coast	0.376	0.298	0.461
Nigeria	0.401	0.334	0.475
Senegal	0.421	0.347	0.501
Total	**0.428**	**0.350**	**0.510**

Table 3 disaggregates digital divide by country and location. Burkina Faso exhibits highest exclusion (DDI=0.51), while Ivory Coast shows lowest (0.38). Rural-urban gap proves substantial across all countries: rural DDI exceeds urban by 0.16 points on average, representing 46% higher exclusion in rural areas. This gap varies from 0.15 (Senegal) to 0.17 (Burkina Faso), suggesting relative uniformity of territorial inequalities across West Africa.

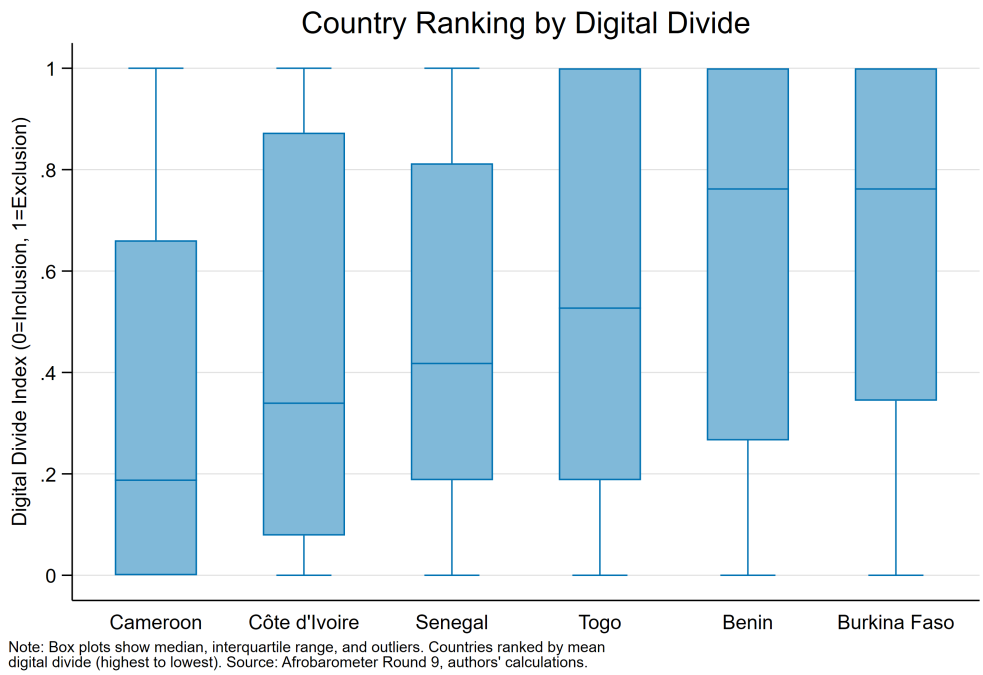

Figure 1: Country ranking by digital divide: a revealing hierarchy

Note: This graph presents the decreasing ranking of countries according to their mean digital divide index, revealing a striking hierarchy among the six West African countries studied. Cameroon displays the lowest divide at 0.109, clearly distinguishing itself with its formal education rate of 83%, the highest in the sample. Senegal follows at 0.148, then Côte d'Ivoire at 0.151. Conversely, Benin presents the highest divide at 0.210. The boxplots also reveal strong within-country variability: Benin and Burkina Faso present particularly marked dispersions, suggesting substantial internal inequalities between connected urban areas and marginalized rural zones. This within-country heterogeneity reminds us that national averages often mask considerable territorial disparities. The graph visually illustrates the correlation between national educational level and digital inclusion, foreshadowing our econometric results which will confirm that formal education constitutes the most powerful determinant of digital inclusion, ahead of even wealth. *Source:* Afrobarometer Round 9, authors' calculations.

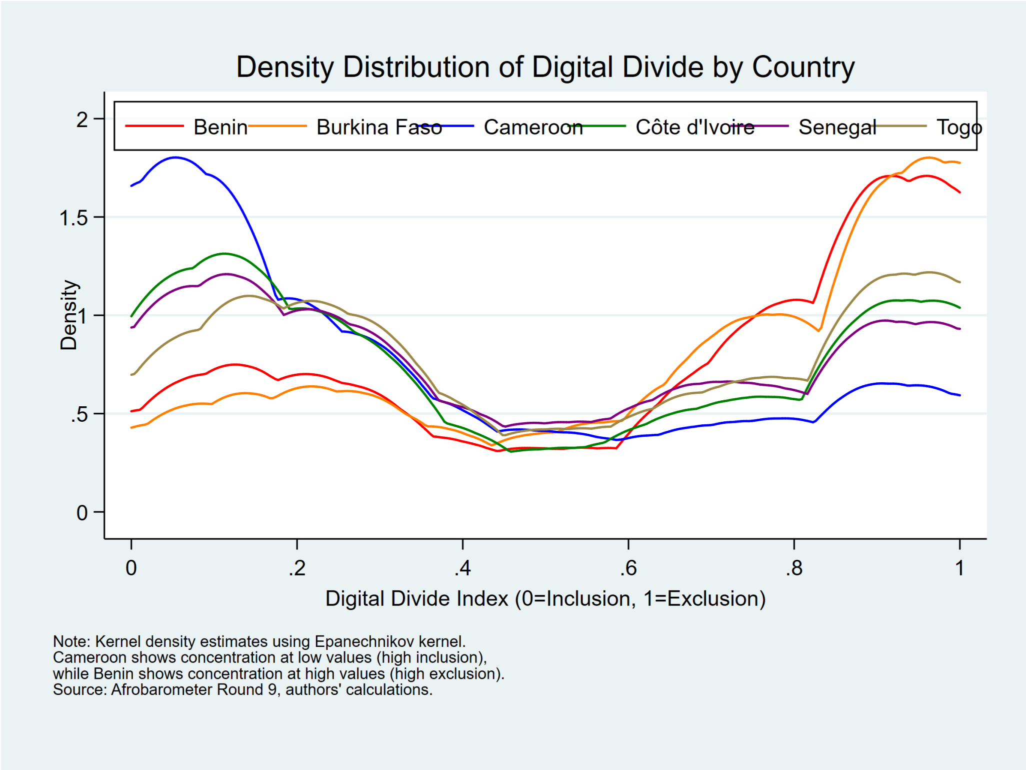

Figure 2: Density distributions of digital divide: contrasting national profiles

Note: The density curves reveal remarkably heterogeneous distributions across countries, going beyond simple mean differences to illustrate distinct national profiles. Cameroon, represented by the blue curve, presents a distribution strongly concentrated around low values, with a pronounced peak around 0.65 on the inclusion scale, signaling that a substantial majority of the Cameroonian population enjoys relatively high digital inclusion. Senegal, orange curve, also shows marked concentration on inclusion with a peak around 0.75. These two countries present unimodal distributions suggesting relative homogeneity of their populations in terms of digital access. Conversely, Benin, red curve, displays a much more spread distribution with a secondary peak around 0.95, revealing the existence of a significant population segment in profound digital exclusion. Togo and Burkina Faso present intermediate profiles with flatter distributions indicating greater internal heterogeneity. These distribution shape differences suggest that West African countries do not simply sit at different levels on a single scale but possibly follow distinct digitalization trajectories. Some appear engaged in progressive inclusion of broad population segments, while others maintain strong polarization between connected and disconnected. These patterns call for differentiated policies rather than a one-size-fits-all approach. *Source:* Afrobarometer Round 9, authors' calculations.

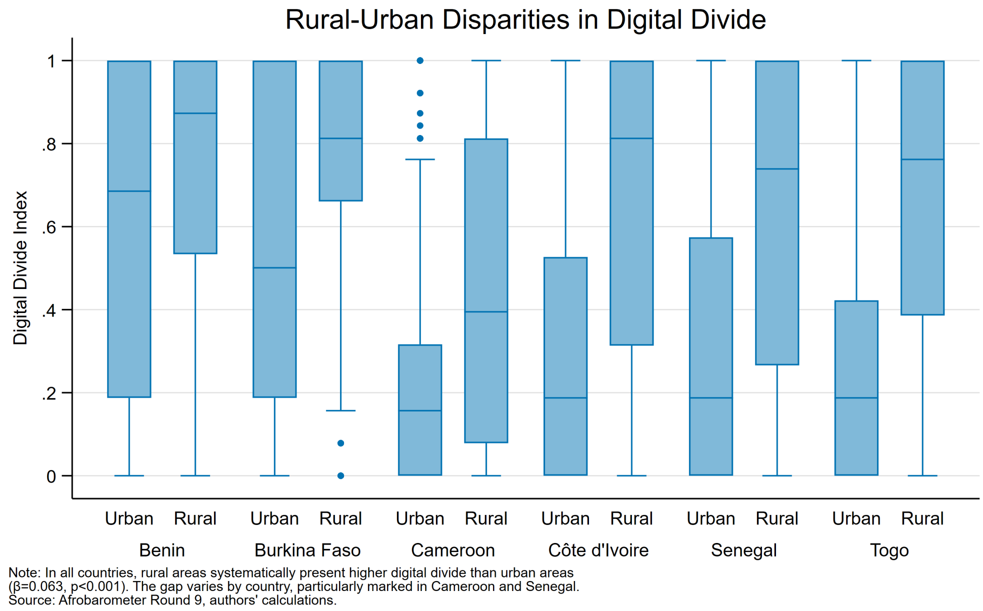

Figure 3: Rural-urban disparities in digital divide: a universal but variable-amplitude gap
Note: This graph systematically compares the distribution of digital divide between rural and urban areas for each country, revealing both constants and instructive variations. One finding immediately emerges: across all six countries without exception, rural areas systematically present higher digital divide than urban areas, empirically confirming the significant effect of location estimated at $\beta = 0.063$ with $p < 0.001$ in our regressions. This universality of the rural-urban gap suggests that underlying mechanisms, including distance to telecom infrastructure, lower affordability, and lower average educational level, operate robustly across national contexts. However, the magnitude of this gap varies notably by country, revealing differentiated national dynamics. Cameroon and Senegal display particularly marked rural-urban gaps: in Cameroon, the urban median sits around 0.15 versus approximately 0.40 in rural areas, a differential of 0.25 points. In Senegal, the gap is comparable. These countries seem characterized by strong concentration of digital inclusion in urban areas while rural areas remain largely disconnected. Conversely, Benin and Burkina Faso present more modest rural-urban gaps, suggesting relative homogenization of digital lag: even urban areas in these countries display exclusion levels comparable to rural areas of more advanced countries. This compression of the gap reflects not better rural inclusion but rather generalized lag including urban areas. This finding nuances targeting policies: in some countries like Cameroon, prioritizing rural areas seems pertinent, while in others like Benin, a more universal approach including disadvantaged urban neighborhoods appears necessary. *Source:* Afrobarometer Round 9, authors' calculations.

4.2 Determinants of Digital Divide

Table 4 presents estimation results of model (2). Column (1) shows baseline specification with individual variables only. Column (2) adds district-level diversity indices. Column (3) introduces country fixed effects.

Table 4: Determinants of Digital Divide (OLS)

	Dependent variable: DDI		
	(1)	(2)	(3)
Age (years)	0.0018***	0.0017***	0.0016***
	(0.0003)	(0.0003)	(0.0003)
Male	$-0.0521***$	$-0.0518***$	$-0.0515***$
	(0.0065)	(0.0065)	(0.0066)
Formal education (years)	$-0.0312***$	$-0.0308***$	$-0.0305***$
	(0.0012)	(0.0012)	(0.0013)
Wealth index	$-0.0267***$	$-0.0264***$	$-0.0251***$
	(0.0021)	(0.0021)	(0.0022)
Urban	$-0.0823***$	$-0.0797***$	$-0.0776***$
	(0.0089)	(0.0091)	(0.0093)
Social capital index	$-0.0712***$	$-0.0698***$	$-0.0681***$
	(0.0134)	(0.0135)	(0.0137)
Ethnic fractionalization		0.0421**	0.0389*
		(0.0187)	(0.0201)
Religious fractionalization		0.0278	0.0251
		(0.0213)	(0.0225)
Country fixed effects	No	No	Yes
Observations	10,800	10,800	10,800
R-squared	0.387	0.391	0.402

Robust standard errors clustered at district level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Results robustly confirm hypothesis H1. Formal education emerges as most powerful determinant: each additional year reduces DDI by 0.031 points (column 3), representing approximately 10% of standard deviation. This effect dominates wealth (−0.025 per wealth point) and urban location (−0.078). An individual with 12 years of schooling exhibits DDI 0.37 points lower than someone without schooling, all else equal. This massive effect underscores education's centrality in digital inclusion beyond simple purchasing power.

Wealth significantly influences digital divide, though less than education. Each additional point on 0-10 wealth scale reduces DDI by 0.025. Gap between poorest (wealth=0) and richest (wealth=10) represents 0.25 points, substantial but inferior to education's effect.

Gender shows systematic disparity: men exhibit DDI 0.052 points lower than women, controlling for education, wealth, and other factors. This gender gap likely reflects differential socialization in technology use and persisting inequalities in access to technical training.

Urban location strongly reduces exclusion (−0.078), even controlling for individual characteristics. This residual urban advantage likely reflects better infrastructure (signal coverage, electricity) and network effects (proximity to digitally competent peers).

Age positively correlates with digital divide (0.0016 per year), though effect remains modest. A 20-year age gap corresponds to only 0.032 points increase in DDI. Digital divide therefore primarily reflects socioeconomic factors rather than generational effects.

Social capital significantly reduces exclusion (−0.068), supporting compensatory hypothesis. Strong local networks facilitate access to equipment and informal learning. However, this effect remains modest compared to education's impact.

Ethnic fractionalization significantly increases DDI (0.039, column 3), confirming that diversity complicates collective provision of digital infrastructure. Religious fractionalization shows similar sign but remains statistically insignificant, perhaps because religious networks sometimes facilitate resource mobilization independently of homogeneity.

4.3 Association between Digital Divide and Service Access

Table 5 presents estimation results of model (3) for three services. All specifications include district fixed effects and cluster standard errors at district level.

Table 5: Association between Digital Divide and Service Access

	Dependent variable		
	Piped water (1)	Health clinic (2)	Primary school (3)
DDI	−0.218 * **	−0.157 * **	−0.089 * **
	(0.0312)	(0.0287)	(0.0198)
Age	−0.0003	0.0002	0.0004*
	(0.0004)	(0.0003)	(0.0002)
Male	0.0089	0.0067	0.0021
	(0.0087)	(0.0079)	(0.0054)
Formal education (years)	0.0078***	0.0052***	0.0031**
	(0.0016)	(0.0014)	(0.0010)
Wealth index	0.0342***	0.0189***	0.0087***
	(0.0028)	(0.0025)	(0.0017)
Urban	0.1523***	0.0687***	0.0321***
	(0.0118)	(0.0107)	(0.0073)
Social capital index	0.0423**	0.0312**	0.0187*
	(0.0176)	(0.0159)	(0.0109)
District fixed effects	Yes	Yes	Yes
Observations	10,800	10,800	10,800
R-squared	0.512	0.467	0.398

Robust standard errors clustered at district level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Results strongly confirm hypothesis H2: digital divide is systematically and significantly associated with reduced access to all three services. For piped water, DDI coefficient reaches −0.218, implying that moving from complete digital inclusion (DDI=0) to maximum exclusion (DDI=1) reduces probability of piped water access by 21.8 percentage points. Given that only 35% have such access, this represents massive effect.

For health infrastructure, DDI coefficient equals −0.157: digital exclusion reduces probability of living near health clinic by 15.7 percentage points for same one-unit DDI increase. Effect is slightly weaker than for water but remains highly significant and substantial.

For educational infrastructure, coefficient reaches −0.089: complete digital exclusion reduces probability of living near primary school by 8.9 percentage points. Effect is smaller in absolute value but given that 89% already have school access, relative impact remains considerable for excluded populations.

These associations persist despite inclusion of district fixed effects, implying that within same district, digitally excluded individuals live in less well-equipped neighborhoods. This suggests spatial clustering where digital exclusion and service deficits concentrate in same micro-territories.

Individual controls reveal expected patterns. Wealth and urban location strongly predict service access. Formal education positively influences all services, likely reflecting both direct effects (educated households locate in better-equipped neighborhoods) and indirect effects (education facilitates effective demand for public services). Social capital modestly improves access, consistent with literature on collective action.

4.4 Robustness and Heterogeneity

To test robustness of results, we conduct several sensitivity analyses.

Alternative specifications: We re-estimate models using probit instead of linear probability model. Marginal effects (not reported) remain virtually identical, confirming linearity approximates well over relevant probability range. We also estimate models without district fixed effects, replacing them with district-level controls (ethnic/religious fractionalization, urbanization rate). Results (available upon request) show slightly larger DDI coefficients, suggesting some unobserved district heterogeneity attenuates observed associations. Our baseline specifications with district fixed effects therefore provide conservative estimates.

Rural-urban heterogeneity: Table 6 tests whether digital divide associations vary between rural and urban areas by including DDI × Urban interaction terms.

Table 6: Heterogeneity by Location (Urban vs. Rural)

	Dependent variable		
	Piped water (1)	Health clinic (2)	Primary school (3)
DDI	$-0.231***$	$-0.168***$	$-0.095***$
	(0.0387)	(0.0351)	(0.0241)
DDI $\times$ Urban	0.0267	0.0223	0.0124
	(0.0523)	(0.0475)	(0.0326)
Individual controls	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Observations	10,800	10,800	10,800
R-squared	0.513	0.468	0.399

Robust standard errors clustered at district level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Interaction terms prove statistically insignificant for all three services, indicating digital divide associations do not differ significantly between rural and urban contexts. This surprising result contradicts hypothesis H3's geographic component. Digital exclusion penalizes individuals similarly regardless of location. One interpretation: in rural areas, digitally excluded face service deficits due to general infrastructure absence; in urban areas, they face deficits because they concentrate in disadvantaged peri-urban neighborhoods poorly served by basic infrastructure. Mechanisms differ but resulting associations converge.

Social capital as moderator: We test whether social capital attenuates negative association between DDI and services by estimating specifications with DDI $\times$ Social Capital interactions. Results (Table 7) reveal small negative coefficients (meaning high social capital slightly reduces DDI's negative impact), but these interactions remain statistically insignificant at conventional thresholds.

Table 7: Moderation by Social Capital

	Dependent variable		
	Piped water (1)	Health clinic (2)	Primary school (3)
DDI	$-0.235***$	$-0.172***$	$-0.098***$
	(0.0348)	(0.0316)	(0.0217)
DDI × Social capital	0.0412	0.0287	0.0165
	(0.0623)	(0.0566)	(0.0388)
Social capital index	0.0398*	0.0295*	0.0178
	(0.0206)	(0.0187)	(0.0128)
Individual controls	Yes	Yes	Yes
District fixed effects	Yes	Yes	Yes
Observations	10,800	10,800	10,800
R-squared	0.513	0.468	0.399

Robust standard errors clustered at district level in parentheses.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Hypothesis H3 regarding social capital moderation thus receives weak empirical support. Social capital directly facilitates service access but does not significantly buffer against digital exclusion's deleterious effects. This finding aligns with Füzér et al. (2023): in contexts of widespread exclusion, local networks cannot fully compensate for structural deficits.

5 Discussion and Policy Implications

5.1 Summary of Main Findings

Our analysis establishes three robust stylized facts regarding digital divide in West Africa. First, formal education constitutes by far the most powerful determinant of digital inclusion, surpassing wealth, gender, and location effects. This result carries crucial implication: policies focused exclusively on subsidizing equipment or deploying infrastructure will structurally fail if not accompanied by massive educational investment. Digital divide is fundamentally an educational divide.

Second, digital exclusion is strongly associated with deficits in access to drinking water, health, and educational infrastructure. These associations persist even after controlling for individual wealth, education, location, and unobserved district characteristics via fixed effects. Digital divide does not merely reflect preexisting territorial inequalities but constitutes an autonomous dimension of marginalization, spatially correlated with basic service deficits at micro-territorial scale.

Third, contrary to intuition, digital divide's association with services does not vary significantly between rural and urban areas. Digital exclusion penalizes similarly regardless of location, suggesting that marginalization transcends simple rural-urban dichotomy. Policies must therefore target specific populations (uneducated, poor, women) rather than simply geographic zones.

5.2 Theoretical Contributions

Our results enrich contemporary literature on digital divide along several dimensions. We validate for West Africa the multidimensional conceptualization advocated by Van Deursen & Van Dijk (2019): digital divide cannot reduce to binary connected/unconnected but unfolds across multiple levels (equipment, usage, information). Our composite index better captures this gradation than traditional indicators.

We extend to West African context Fu et al. (2024)'s findings on digital technology's inequality-amplifying effect. Digital divide is not neutral regarding access to public goods but systematically correlates with service deficits. This validates concerns about risks of progressive administrative digitalization in contexts of widespread digital exclusion.

We nuance Hollard & Sene (2016)'s optimistic findings on social capital's compensatory role. While social capital facilitates service access, it does not significantly buffer against digital exclusion's negative effects. In contexts of generalized exclusion, local networks cannot substitute for structural public investments.

Finally, we confirm for digital domain Hollard & Sene (2020)'s result on ethnic diversity's negative effect. Ethnic fractionalization significantly increases digital exclusion, likely by complicating collective action necessary for infrastructure provision. This finding underscores importance of inclusive governance mechanisms transcending ethnic cleavages.

5.3 Policy Implications

These results carry direct implications for public policies in West Africa. Current strategies focus primarily on deploying telecom infrastructure and subsidizing equipment. While necessary, these approaches prove insufficient. Our results suggest four complementary policy priorities.

Priority 1: Massive investment in formal education, with particular emphasis on basic digital literacy from primary school. Given education's dominant effect, any digital inclusion strategy must centrally integrate educational dimension. This implies not only expanding school enrollment but also updating curricula to incorporate fundamental digital skills. Countries achieving universal primary education will mechanically reduce digital divide in coming generation.

Priority 2: Targeted subsidies for vulnerable populations, particularly rural women without formal education. Cumulative disadvantages (female gender, rural location, no schooling) create extreme exclusion situations. These populations require specific assistance programs: subsidized equipment, adapted training, facilitator access. Community telecenters staffed with trained facilitators could partially compensate for individual skill deficits.

Priority 3: Guarantee accessible non-digital alternatives during administrative service digitalization. Given strong association between digital divide and service deficits, rapid digitalization risks creating insurmountable barriers. Governments must ensure that every digital service maintains non-digital access channel (physical offices, telephone hotlines, community assistance) for at least transitional period. Otherwise, digitalization will exclude precisely the most vulnerable populations.

Priority 4: Strengthen inclusive local governance mechanisms to mitigate ethnic fragmentation's negative effects. Since ethnic diversity increases digital exclusion by complicating collective action, policies must promote participatory governance bringing together all community components in infrastructure planning. Participatory budgets and deliberative platforms could reduce ethnic tensions and facilitate consensus on digital infrastructure priorities.

5.4 Limitations and Future Research

This study presents several limitations opening avenues for future research. First, cross-sectional nature of data prevents establishing definitive causal relationships. Although district fixed effects control for unobserved territorial heterogeneity, residual endogeneity cannot be fully excluded. Panel studies or natural experiments would better identify causal effects.

Second, our digital divide index, while multidimensional, does not capture all relevant dimensions. It notably omits usage skills (beyond binary usage/non-usage) and tangible benefits derived from technologies. Future work could integrate direct competency measures and concrete usage indicators (administrative procedures online, distance learning, telemedicine).

Third, mechanisms linking digital divide and service access merit deeper investigation. Is association due to spatial concentration (both deficits clustering in same neighborhoods)? To causal effect of digital exclusion on ability to effectively demand services? To digital services' role in facilitating access to traditional services? Qualitative case studies and mediation analyses could elucidate these mechanisms.

Finally, our analysis focuses on six West African countries but cannot generalize to entire continent. Comparative studies including Central, Eastern, and Southern African countries would test robustness of results across different contexts. Digital divide's determinants and implications likely vary according to infrastructure development level and institutional quality.

6 Conclusion

This study posed a crucial question for West Africa's development: to what extent does digital divide amplify inequalities in access to essential services? Our rigorous empirical analysis based on Afrobarometer data and econometric models with district fixed effects establishes three major findings.

First, digital divide is profoundly rooted in educational inequalities. Formal education emerges as by far the most powerful determinant of digital inclusion, ahead of wealth, location, and all other factors. This result demolishes simplistic discourse reducing digital divide to infrastructure or equipment problem. Digital divide is fundamentally an educational divide, reflecting and amplifying preexisting gaps in human capital.

Second, digital exclusion strongly correlates with deficits in access to drinking water, health services, and educational infrastructure. This association persists even after controlling for wealth, education, location, and unobserved territorial characteristics. Digital divide is not merely a symptom of general underdevelopment but constitutes an autonomous dimension of marginalization, spatially concentrated with basic service deficits.

Third, these patterns transcend simple rural-urban dichotomy. Digital exclusion penalizes similarly in both contexts, though via different mechanisms. In rural areas, both digital exclusion and service deficits stem from general infrastructure absence. In urban areas, they concentrate in disadvantaged peri-urban neighborhoods. Marginalization therefore operates through population categories (uneducated, poor, women) more than through geographic zones.

These results carry an urgent message for policymakers. Without deliberately inclusive policies, progressive digitalization of public services and economic activities risks creating new exclusion barriers for already vulnerable populations. The risk is real: administrative digitalization without universal digital inclusion will structurally exclude those who already face greatest difficulties accessing public services.

Viable policy response requires simultaneously acting on multiple fronts. Massively invest in universal formal education integrating basic digital skills from primary school. Deploy targeted programs for currently excluded adults, particularly rural women. Guarantee accessible non-digital alternatives during administrative service digitalization. Strengthen inclusive governance mechanisms to overcome ethnic divisions hindering collective infrastructure provision.

Digital divide in West Africa is not inevitable technological fatality. It results from policy choices, resource distribution, and institutional priorities. With adequate political will and well-calibrated redistributive policies, digital technology can become authentic lever for reducing rather than amplifying inequalities. But absent such voluntarism, it will mechanically worsen existing fractures.

The next decade will prove decisive. Current choices regarding digitalization, education, and redistribution will determine whether West Africa successfully navigates digital transition toward more inclusive development, or whether it sees technological progress paradoxically deepen social divides. Stakes could not be higher: it concerns nothing less than the future of hundreds of millions of individuals and sustainability of social cohesion in a rapidly transforming region.

Our results suggest only one viable path: that of inclusive digitalization deliberately prioritizing most vulnerable, investing massively in universal education, and maintaining multiple service access channels during transition. This path is demanding but not impossible. It requires political courage to resist siren calls of rapid digitalization at any cost, and wisdom to understand that technological progress only becomes genuine human progress when equitably shared. West Africa stands at this crossroads. Time to choose has arrived.

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